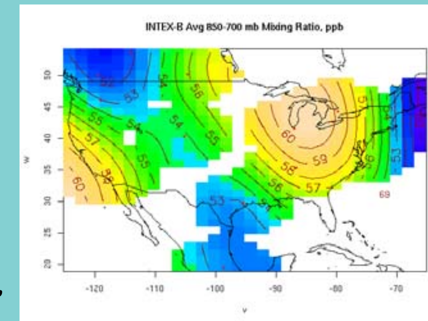
Ames Research Center

LOCKHEED MARTIN

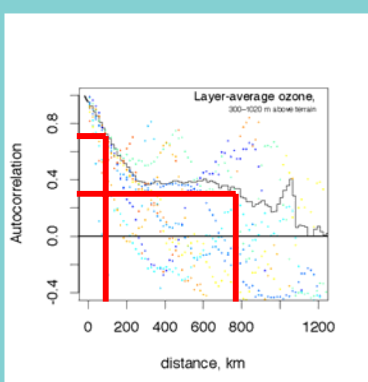
Learn-from-Aura:
Reflective
UV-IR Mappers



Variability of Tropospheric Ozone Relevant to Smog — Forecasting and Abatement

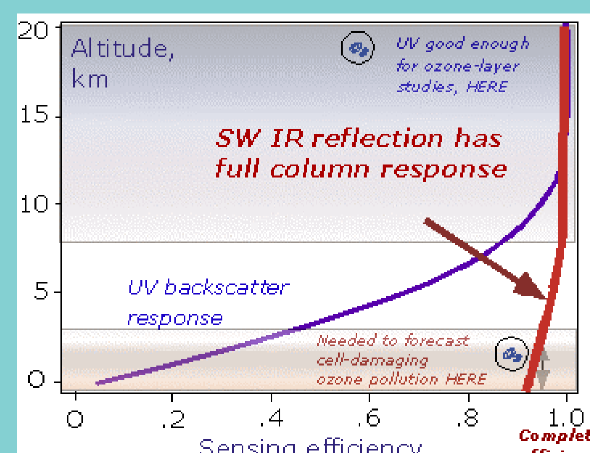
- *Views of the lower atmosphere accessible by current technology:*
  How often and how close together do we need samples?
  – the general satellite sampling problem with clouds/bad-spots
- *What need to measure, understand, and forecast large-scale smog ozone ?*

Can we get 0–3 km ozone and predictors with synergistic SWIR (3–3.6 µm) and UV measurements?



R. B. Chatfield and R. Esswein,
NASA Ames Research Ctr.;
(J. B. Kumer, J. L. Mergenthaler, A. E. Roche,
Lockheed Martin Advanced Technology Ctr)

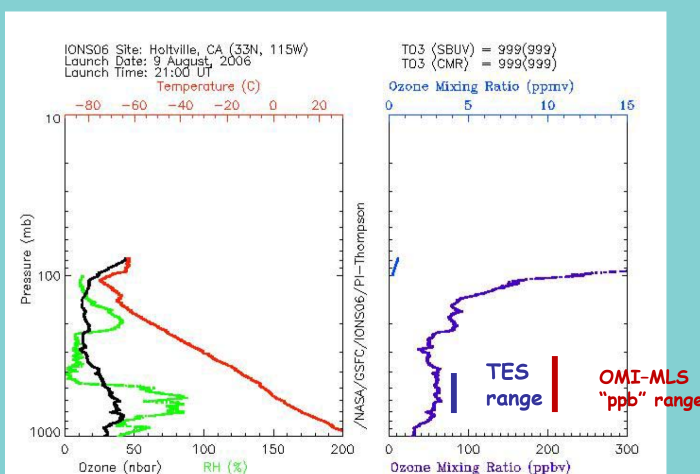
Aura-Val *Sept 11, 2006*

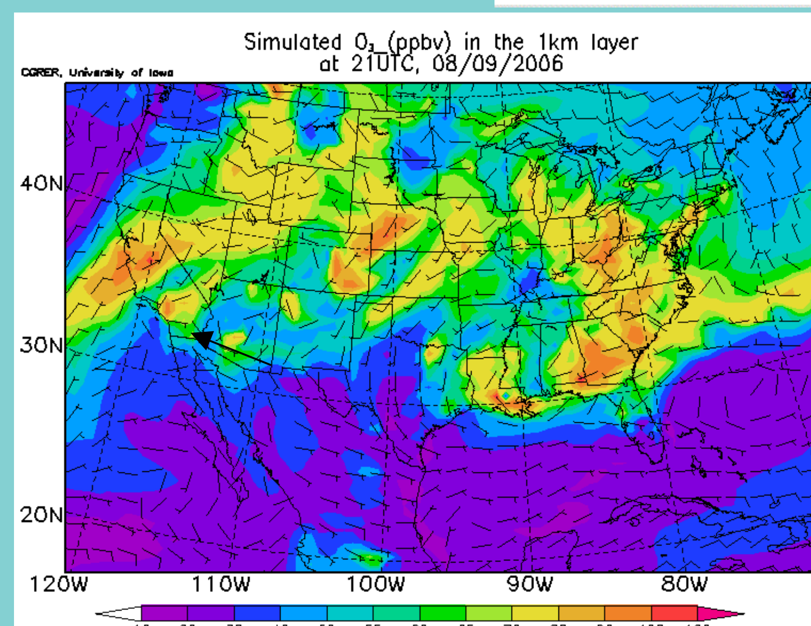


Environmental Protection Agency AMI

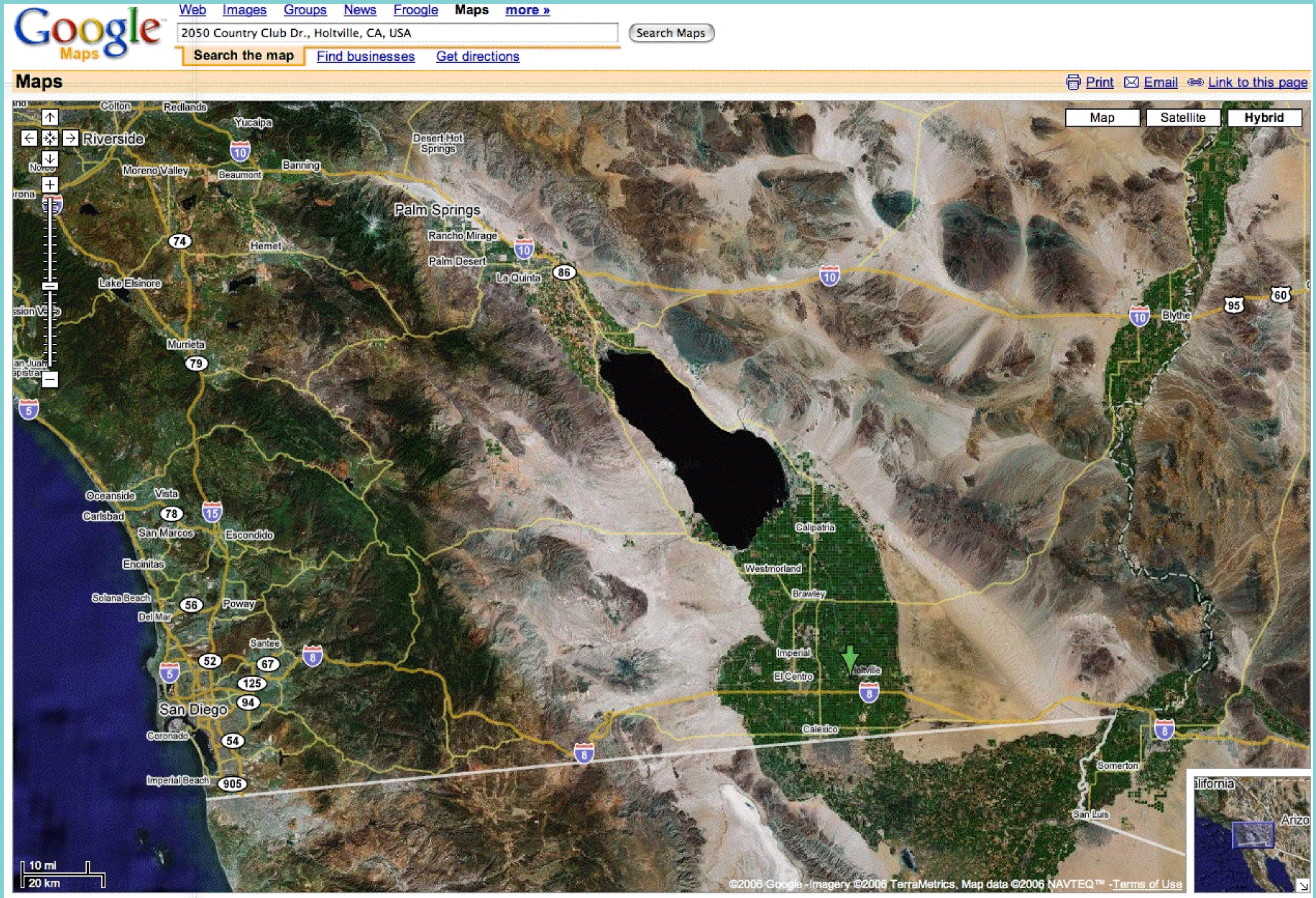
- Largely funded by an Advanced Measurements Initiative (AMI)

- California Air Resources Board
  bought 1/2 sondes, Aura Val. 1/2
- Brings in EPA Reg. 9, Reg. 6, Southwest "SCERP"
  Cal. Berkeley

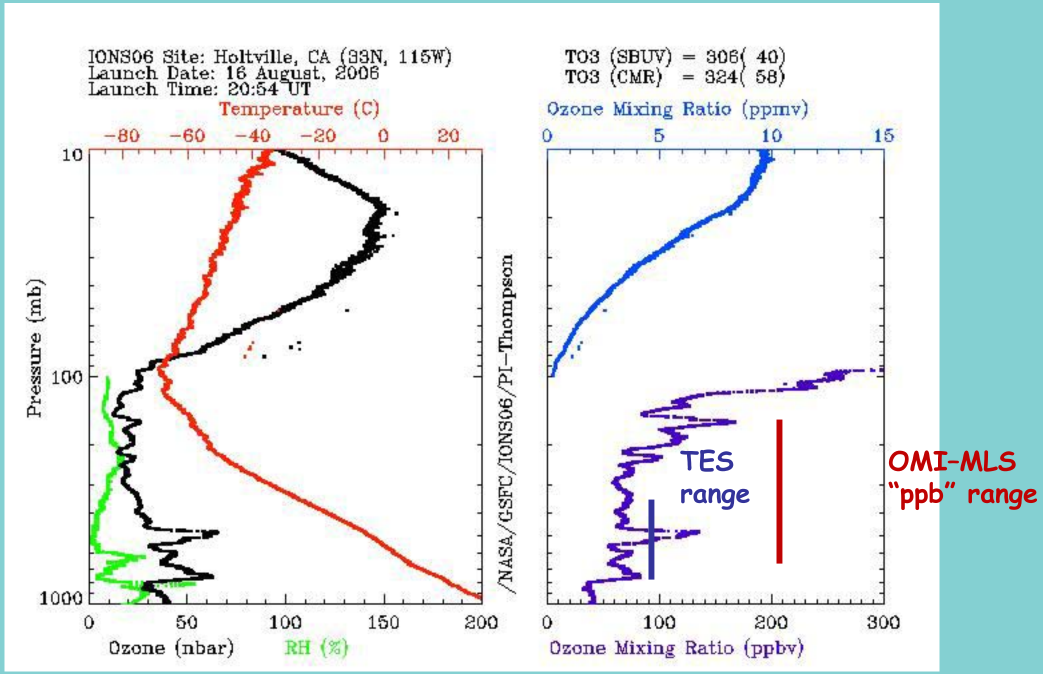


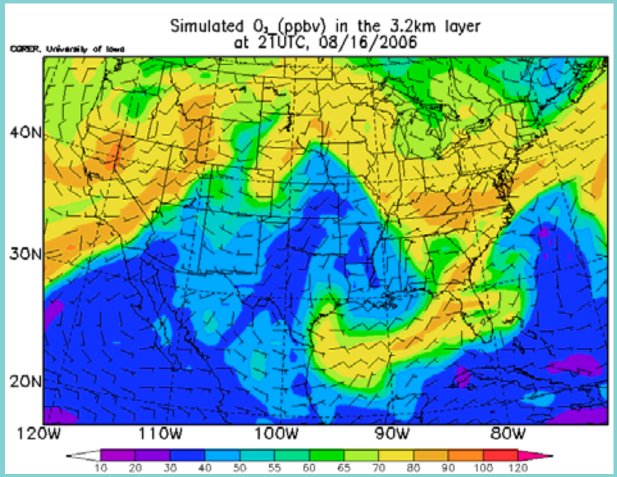


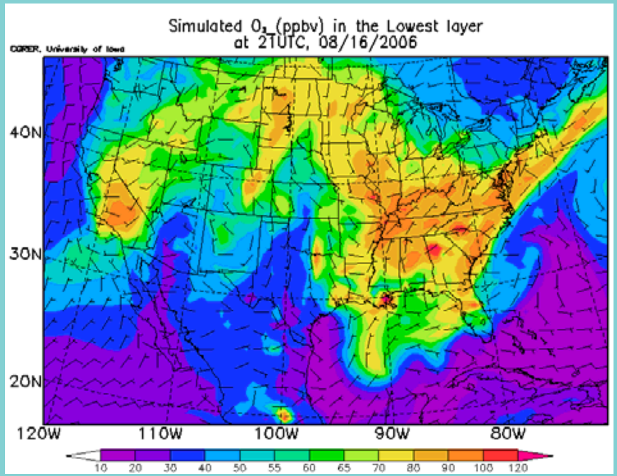
Using satellite data to understand smog ozone: a very current example



- Layering of ozone in PBL and elevated layers … strong

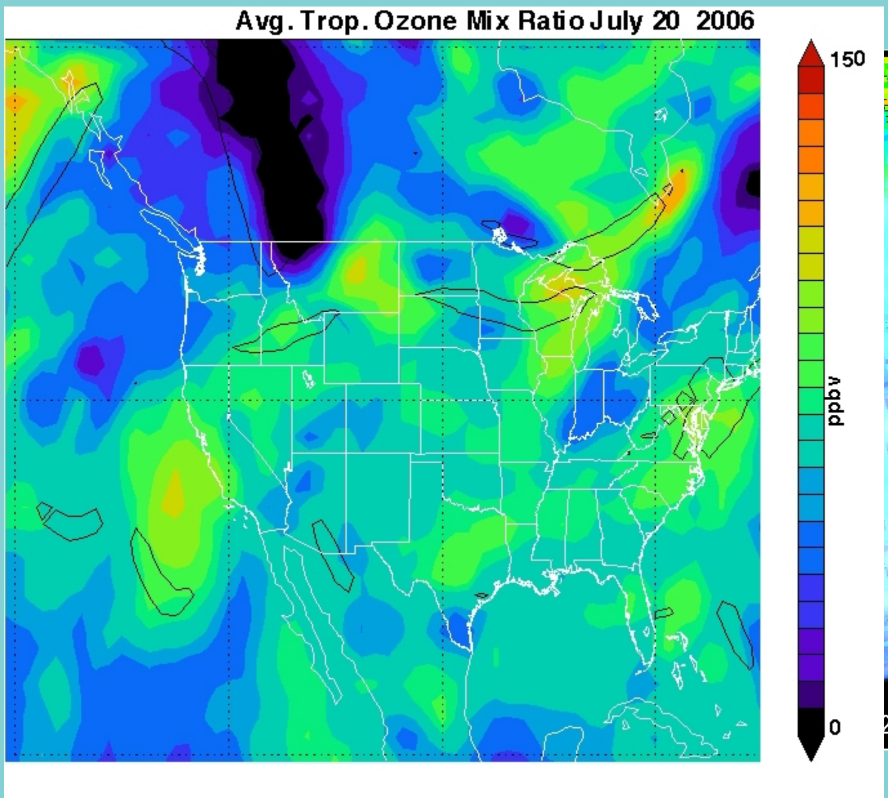


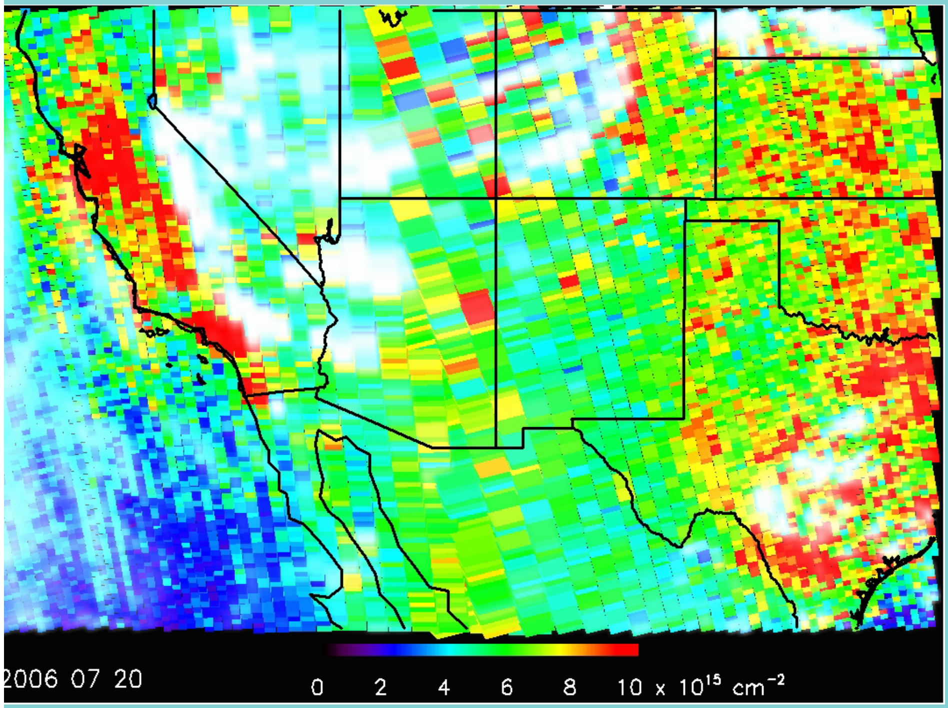




Northern/Western California Heat Wave and Smog Episode

Note footprint width towards limb





- **OMI tropospheric O_3 sees some effects:** Mark Schoeberl, GSFC (Contours are front/stratosphere indicators)
- OMI tropospheric NO_2 sees clearly, but describes O_3 generation, not O_3 (Gleason/Bucsela, GSFC).

How well are we doing with OMI-MLS (Schoeberl technique) … compared to Browell DIAL Tropos. Ozone Mixing Ratio Weighted Average (whole column average)

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Graphics decompressor
are needed to see this picture.

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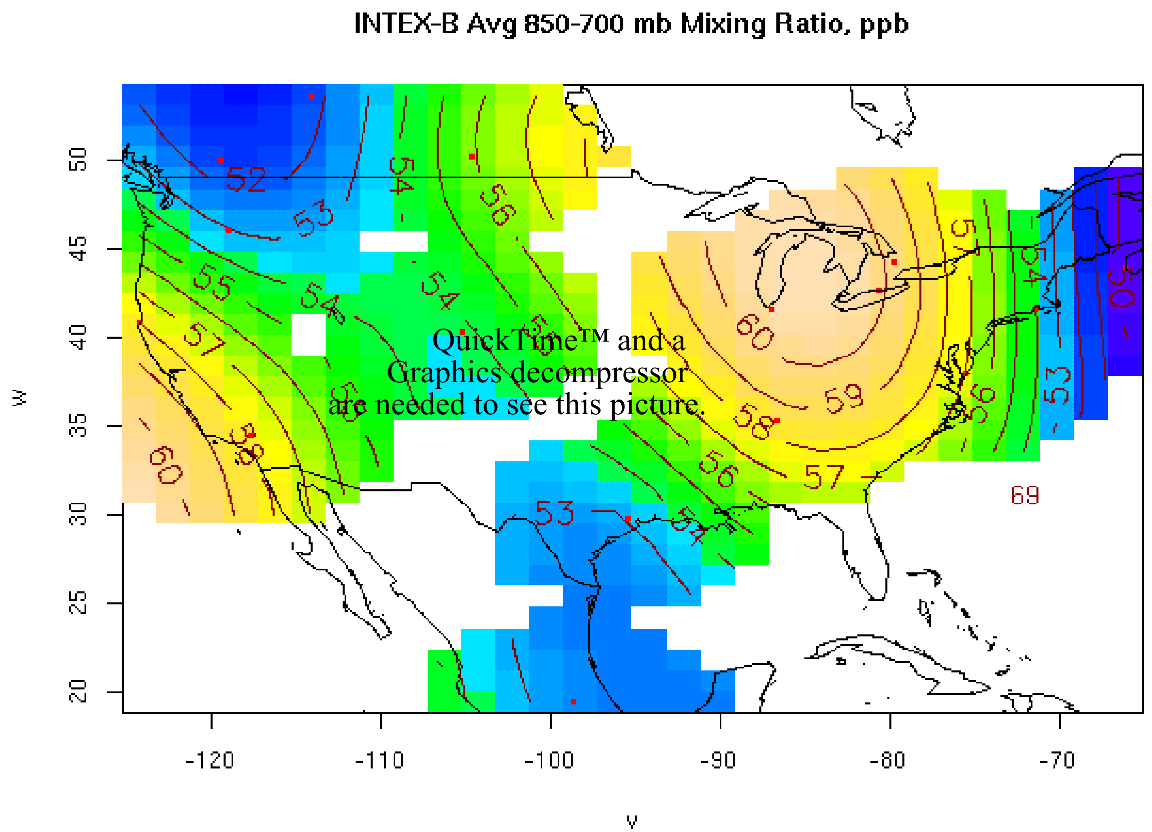
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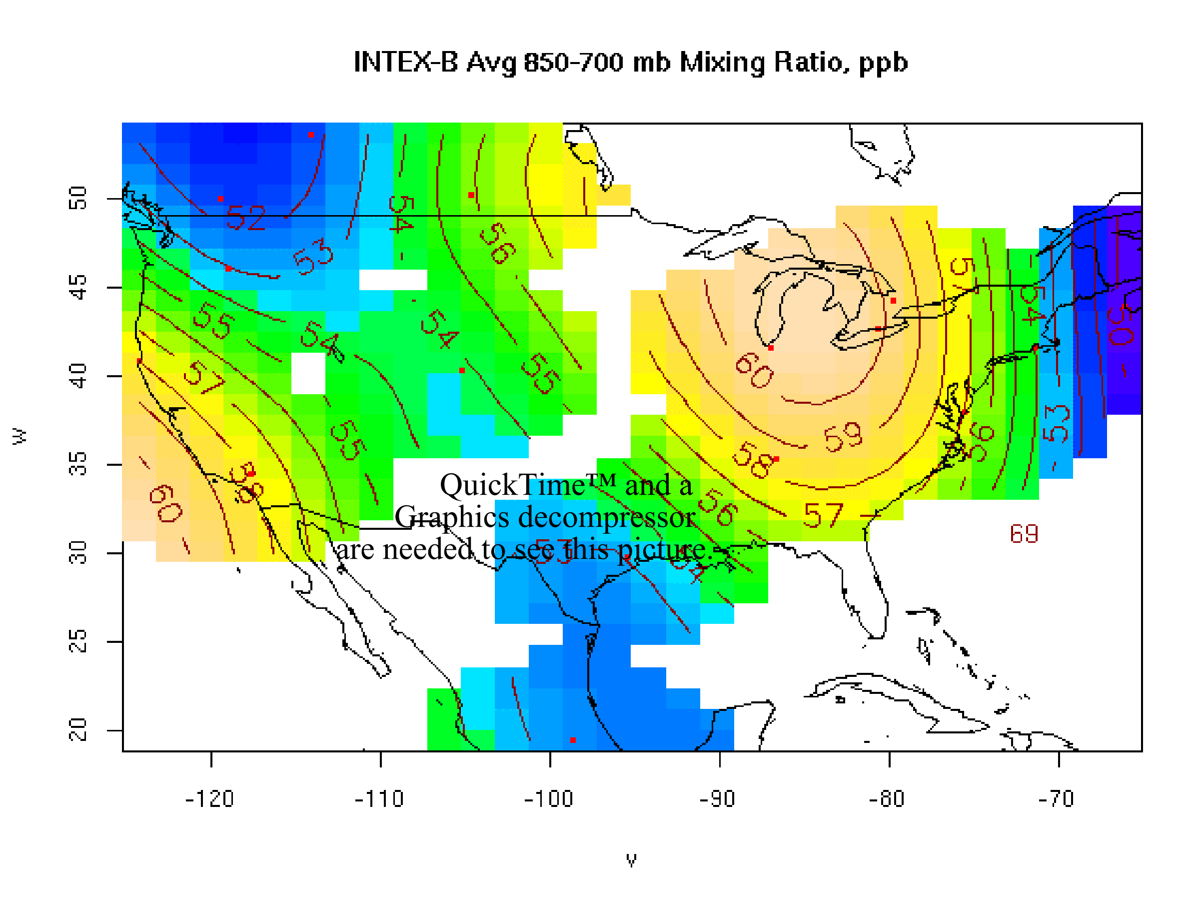
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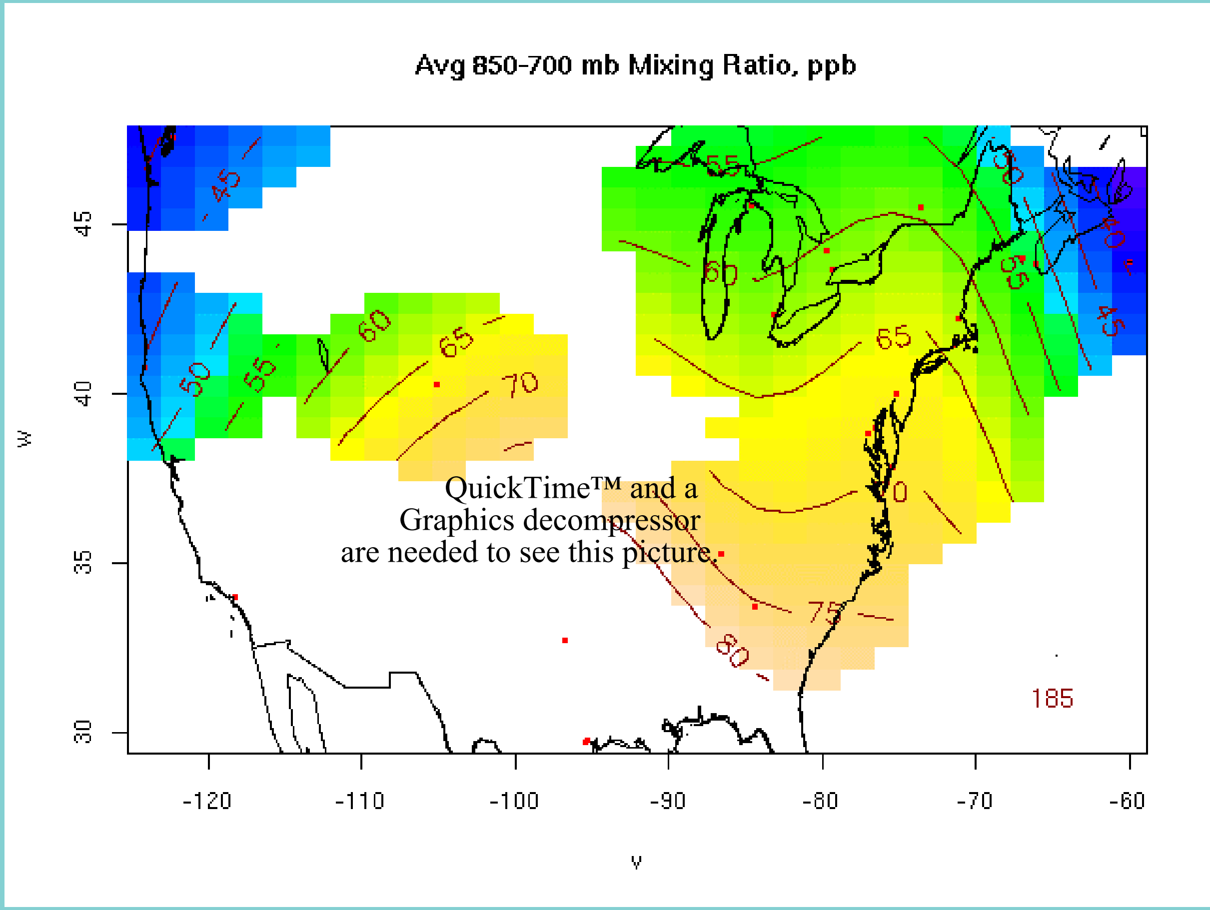
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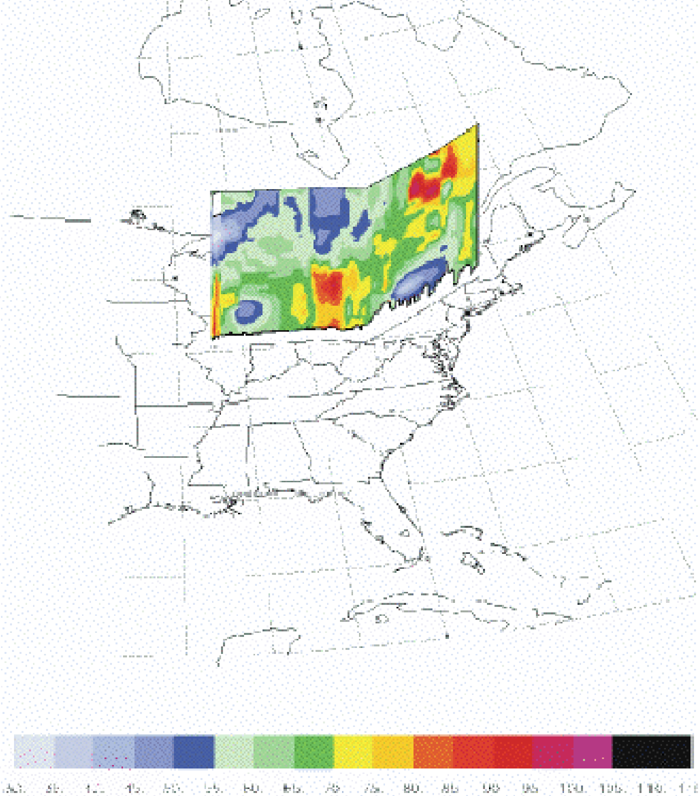
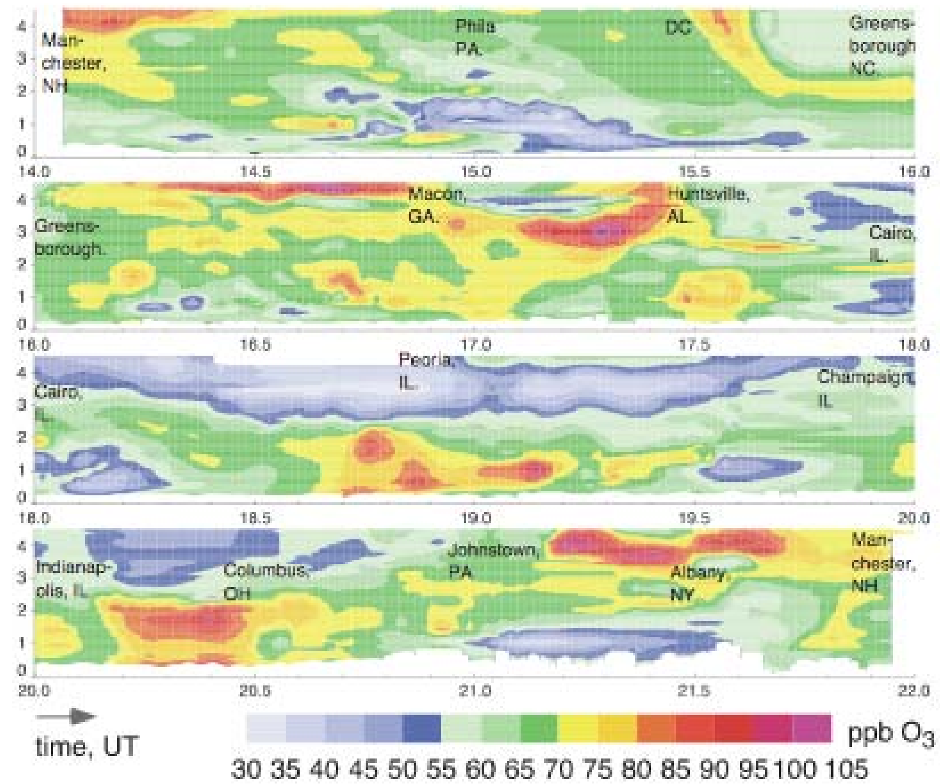
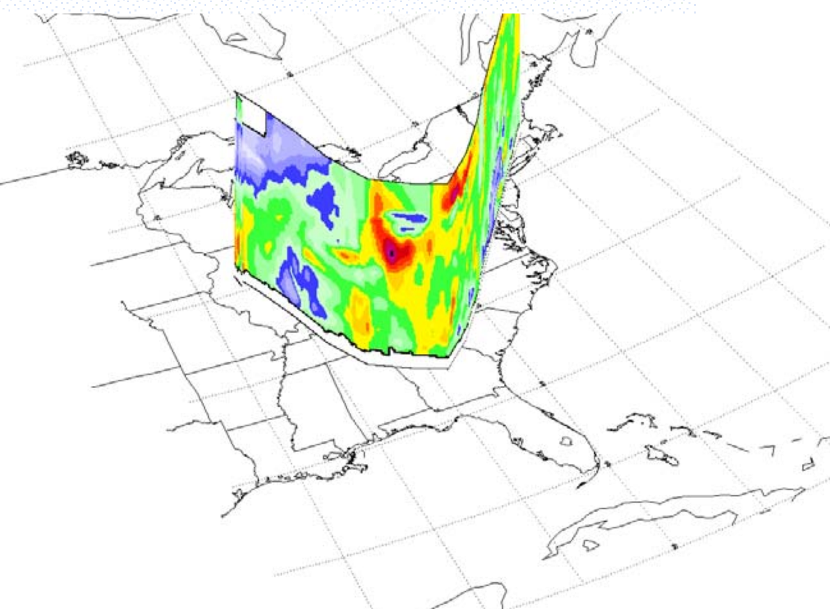


Ozone's variability

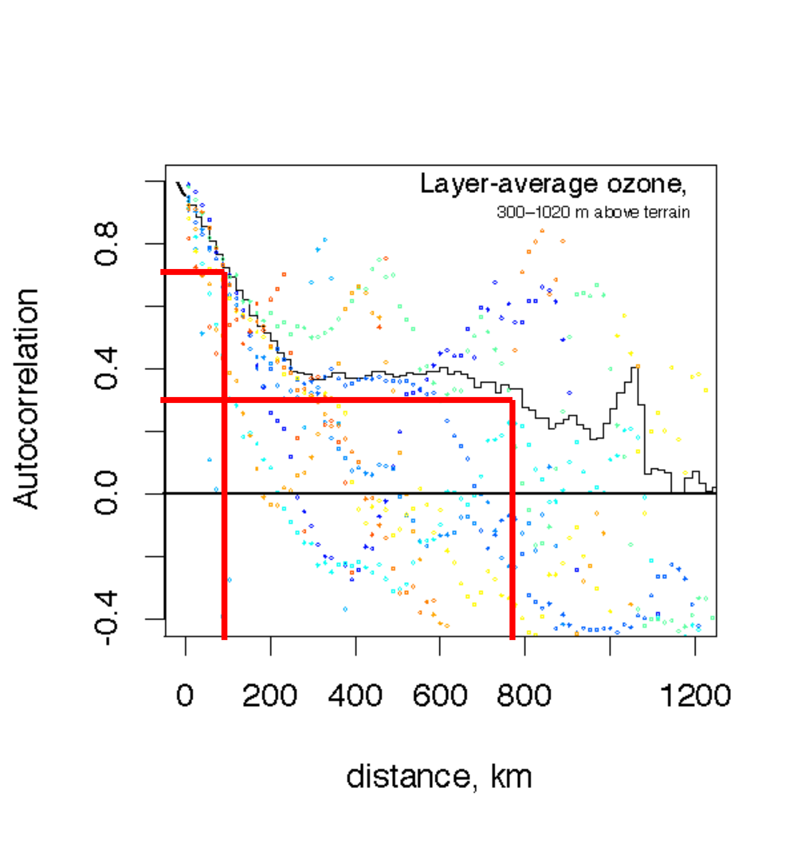
DIAL Differential Absorption LIDAR, …by Ed Browell and the Langley LIDAR team See: Chatfield et al., 2006a





Note layering 0–1.3(?) km, 1.3m–3 km, similarity of values, and signs of interaction (via clouds?)

Autocorrelations Spatial Scales Drawn from DIAL LIDAR samples, INTEX-NA (ICARTT), July-Aug. 2004



Layer average, 300–1020 m

c = 0.7 … 50% variance explained

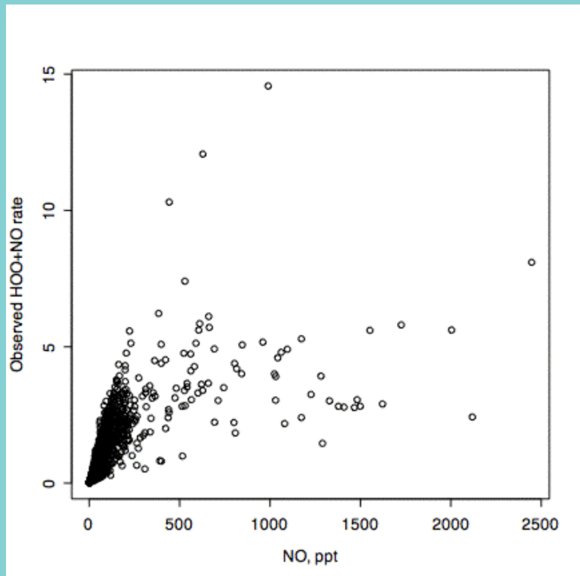
c = 0.36 defines “spatial scale”

What’s going on: local (plume/antiplume effects) vs regional tendencies?)

Can we measure smog ozone production from space, … if only we can measure smog ozone?

- $P_{O3} \sim f\,(\,j_{HCHO\text{->}rads} \times HCHO\,,\quad NO\,)$
- ***HCHO and $j_{HCHO\text{->}rads}$ are measurable***

  (j is ~ UV reflected radiation)
- ***NO derivable from NO_2, O_3, if O_3 is known!***

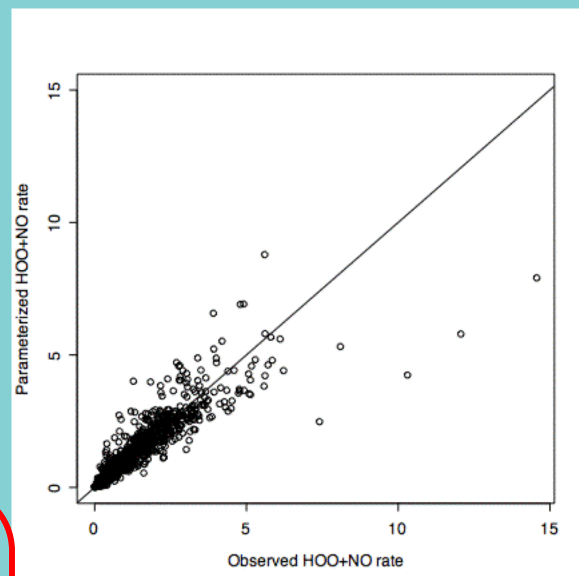


$P_{O3} \sim f(NO)$

only NO … well known

Chatfield et al., 2006a (sub. to J. Geophys. Res.)

Ozone production is taken to be the principle term (~60%) … big discussion if more modeling is better!

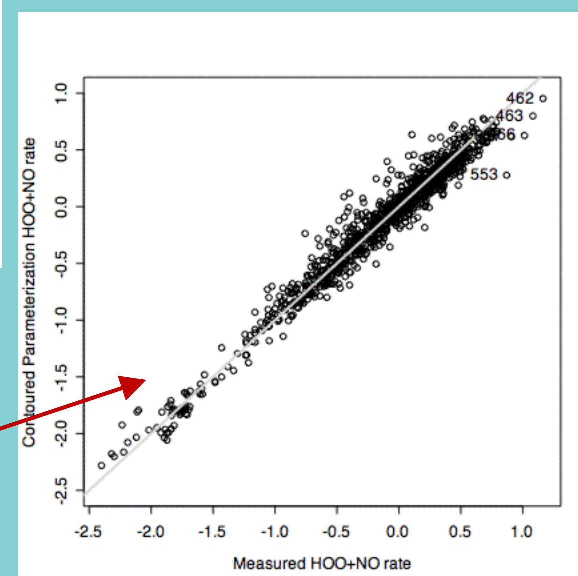


$P_{O3} \sim f(\, j_{HCHO\text{->}rads} \times HCHO \times NO \,)$

Single "Index Variable"

"Contour-plot method" more like full-model constraint

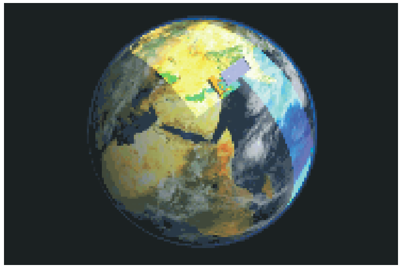
$P_{O3} \sim f(\, j_{HCHO\text{->}rads} \times HCHO \;,\; NO \,)$



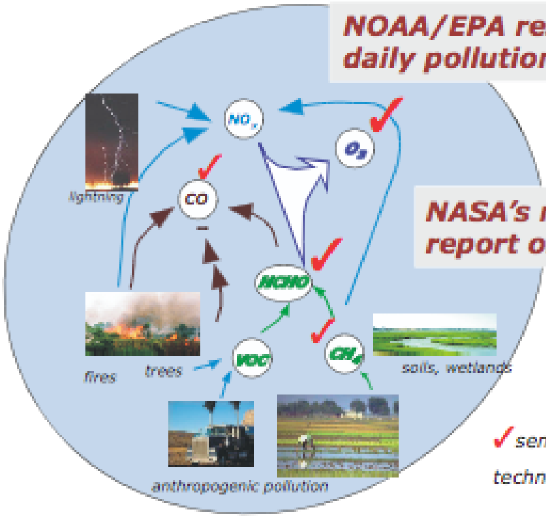
Chatfield et al., 2006b (for Atmos. Environ.?)

Robust Infrared Mapping for Tropospheric Ozone Prediction

R. Chatfield / Ames, J. Kumer, A.Roche, J. Mergenthaler / L-M ATC Palo Alto,
L. Strowe / UM BC, ... K. Chance / Harvard-Smithsonian Astrophysics



NOAA/EPA responsiblity for daily pollution forecasts



NASA's mandate to report on Earth's ozone

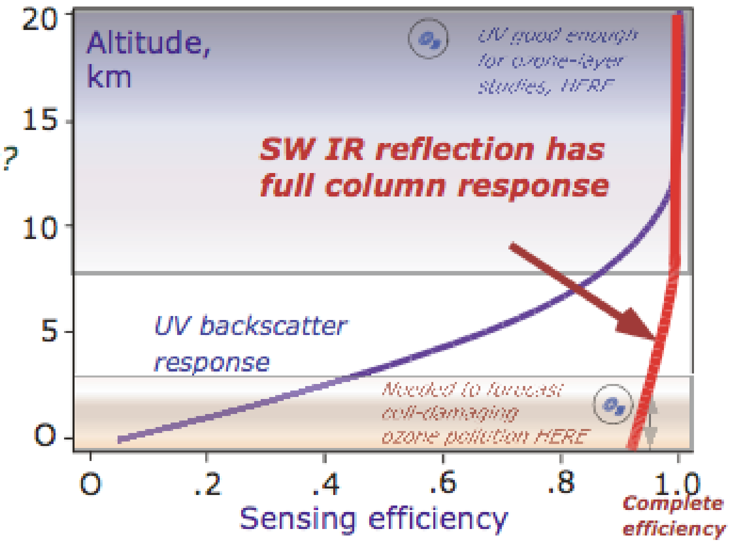
✓ sensed by this technology !

Tropospheric Infrared Mapping Spectrometry

- **Elegant, small, robust, cheap: Grating Mapping Spectrometers have ONE MOVING PART, vis: Cal On/Off ... ~20 kg + radiative cooling, etc.**
- *Daily, global maps to highlight regional and long-distance pollution threats.*

- *UNEXPLORED reflective IR wavelengths usable with new detector technology: complement or supplant limited UV techniques?*

TIMS adds tropospheric information allowing 0–2 km O3 to ~15% per area



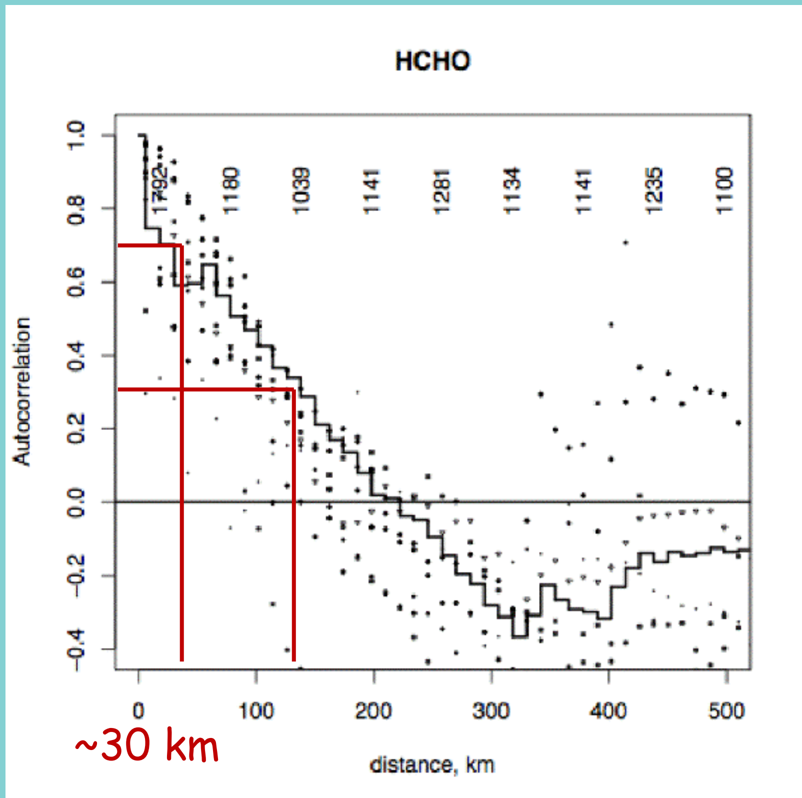
A Basic Demonstration Sensor Set: O_3 and HCHO

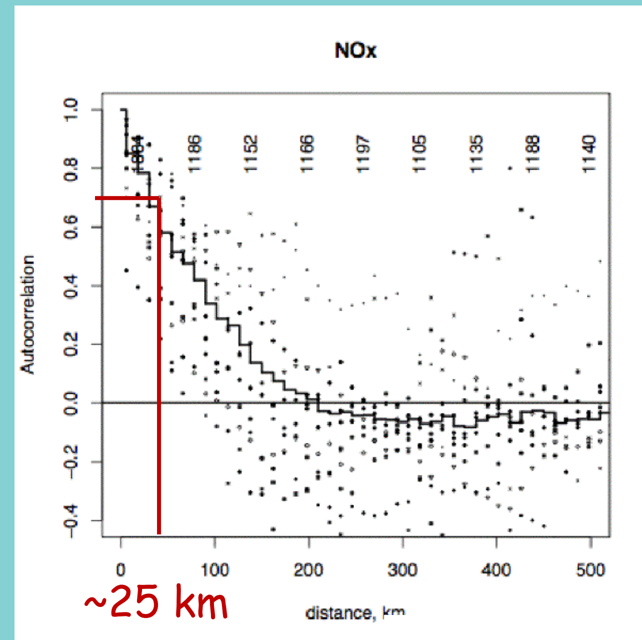
Spectral Region	Approx. λ	Frequency resolution	Nadir ELF [1]	Primary Measurement (potential measurement)	Consequent Additional Benefits
SWIR	3.56 μm	< 0.35 cm^{-1}	3.2 km	HCHO, CH_4, N_2O, and maybe some O_3 info	HCHO summarizes pollution Volatile Organic Carbon compound smog-activity; high precision column info and some vertical info for HCHO, CH_4 & N_2O
SWIR	3.3 μm	< 0.35 cm^{-1}	3.2 km	O_3, CH_4 Good reflectivity	Adding 2nd slit gives more O_3 sensitivity

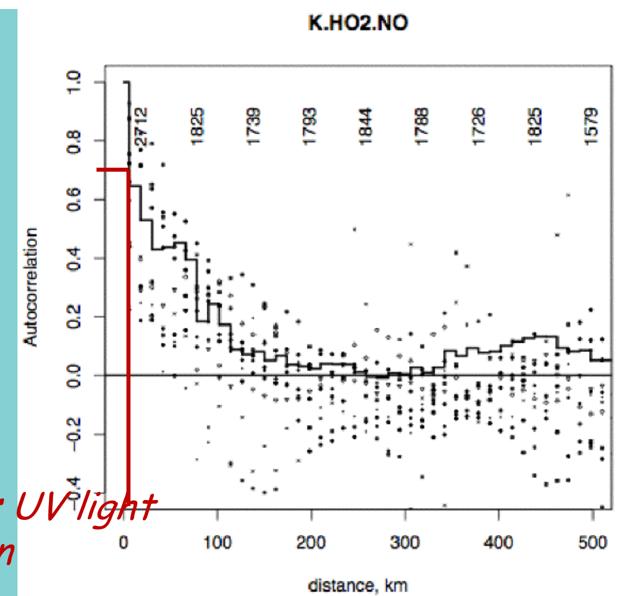
1- ELF: Elemental (smallest sampled) footprint
2- BL: Planetary Boundary Layer

Autocorrelation scales for HCHO, NO_x

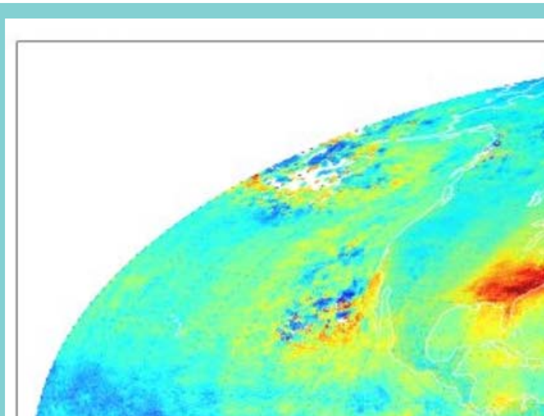
Chatfield et al., 2006a (sub. to J. Geophys. Res.)







includes UV light variation



Averaged OMI HCHO data does not show detail

Thanks to T. Korosu

Can we indeed see Smog PBL ozone?

Classic LEA for simply emissive MWIR

First try with partially emissive surfaces

Table 4.2 Results for O_3 partial columns for retrieval from various data sets with MWIR& SWIR albedos = 0% & 8%

data use[1]	MWIR only			MWIR and SWIR		
O_3 partial columns	prc [2] (%)	A_{II}	C_{RII} (%)	prc (%)	A_{II}	C_{RII} (%)
0 - 2 km, clean	92.6	0.14	100	97.0	0.24	100
0 □2 km, polluted	80.1	0.36	100	61.0	0.63	100
2 - 12 km	6.2	1.00	100	6.0	0.99	100
12 - 22 km	1.2	0.98	10	1.4	0.98	10

Results for O_3 partial columns for retrieval from various data sets with both the MWIR & the SWIR α = 8%

data use[1]	MWIR only			MWIR and SWIR		
O_3 partial columns	prc [2] (%)	A_{II}	C_{RII} (%)	prc (%)	A_{II}	C_{RII} (%)
0 - 2 km, clean	51.6	0.73	100	49.8	0.75	100
0 - 2 km, polluted	20.9	0.96	100	19.9	0.96	100
2 - 12 km	5.2	1.00	100	5.2	1.00	100
12 - 22 km 15%	1.3	0.98	10	1.3	0.98	10

Notes **1** daytime case with a = 8% for both the MWIR and the SWIR. Only the MWIR spectral data are used for the first case, then both the MWIR and the SWIR data are used for the 2nd case.
2 prc is retrieval precision, A_{II} the diagonal of the averaging matrix and C_{RII} the square root of the diagonal element of the solution covariance matrix. The

See Kumer et al. presentation, SPIE-6299-40 later